Characterization of Structural Behavior and Properties of Braided Composites

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ABSTARCT

Braided composites have good properties in mutually orthogonal directions, more balanced properties than traditional tape laminates, and have potentially better fatigue and impact resistance due to the interlacing. Another benefit is reduced manufacturing cost by reducing part count. Because of these potential benefits these braided composites are being considered for various applications ranging from primary/secondary structures for aerospace structures. These material systems are gaining popularity, in particular for the small business jets, where FAA requires take off weights of 12,500 lb. or less. The advantages of braids are a result of the interlacing, but this interlacing also complicates the stress analysis and so makes it more difficult to design with confidence. Before these braided fabric laminated composites can be used in primary structural applications, predictions of the modulii and Poisson's ratios from the braid architecture and the properties of the constituents are desirable. It is also desirable to compare the structural response (e.g. stresses and deformation) of braided fabric laminated composites with the conventional multidirectional laminates. There are various parameters that characterize the weave architecture of braided composites. Analytical and/or finite element models are necessary to study the effects of these parameters on the behavior of braided fabric composites and to design an efficient braided structure for a particular application.

The present research addresses the performance evaluation and modeling of low cost manufactured braided composites. Vacuum Assisted Resin Transfer Molding (VARTM), is low cost, affordable and suitable for high volume manufacturing environment. Recently the aircraft industry has been successful in manufacturing wing flaps, using carbon fiber braids and epoxy resin and the VARTM process (see Figure 1). The research presents fabrication of carbon fiber braids using 2 x 2 Biaxial Carbon (AS4) Braided Sleevings: GAMMASOX GH2.00 (Heavy Duty, 2î diameter when braid angle 45^{0}, 12K tow size) made by A & P Technology Inc. and Derakane Momentum 411-350 Epoxy Vinyl Ester resin made by Dow Chemical Company Inc. using VARTM process. VARTM fabricated braided composite panels were cut into tensile, shear and compression specimens. These specimens were tested to determine the fundamental properties of braid.

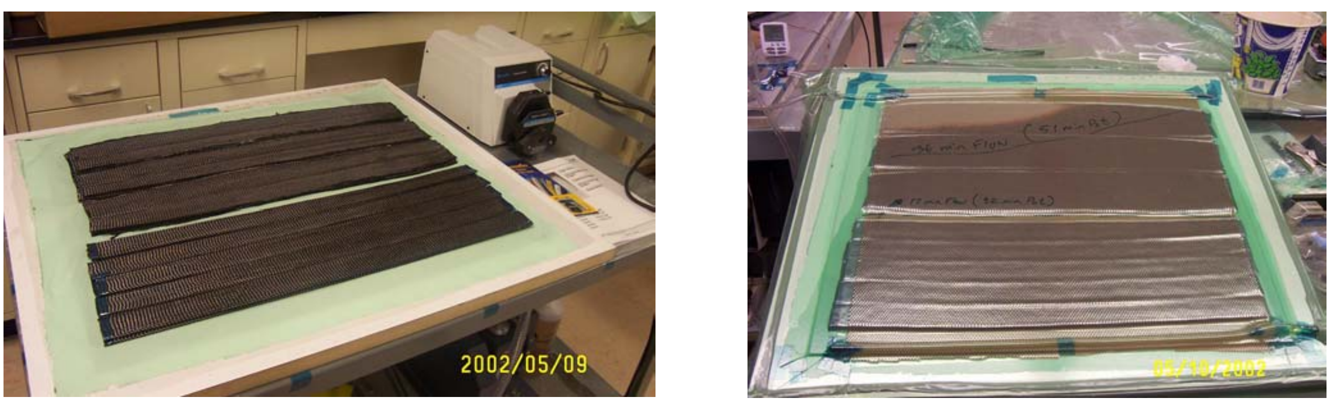

Figure 1. VARTM Processing of Carbon Braids

Research also presents predictive finite element models for braided composites that will allow optimal design of braided composite structures. Unlike most weaves, the tows in a braid do not run in orthogonal directions. This results in an unusual shape for the cross-over region (see Figure 2). This research presents a repeated pattern of interlacing (periodicity). If the periodicity is exploited, finite element models can be developed for a single representative volume element (RVE) that will behave as though it is surrounded by many other RVEís. The appropriate boundary conditions for the RVE (which involve numerous multi-point constraints) have been derived. The analysis region was further reduced even further by using the symmetries within a single RVE. Unfortunately, the boundary conditions for such a partial RVE model are not intuitively obvious. The research presents a general strategy for deriving the boundary conditions. For this particular braid, exploiting the symmetries allows FEA analysis using only one half of the RVE. For some textiles, there are greater symmetries and the savings are even greater. To check the boundary conditions, finite element models for both the half and quarter unit cells were developed and analyzed for a symmetrically stacked composite. The half unit cell is a reasonable substitute for the full unit cell model as a reference since the boundary conditions on the top and bottom of the model are quite simple (see Figure 3). The results obtained by using the present finite element model are compared with the experimental results.

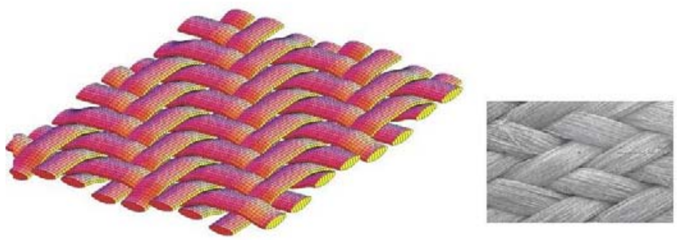

Figure 2. Finite Element Model of 2x2 Biaxial Carbon Braid

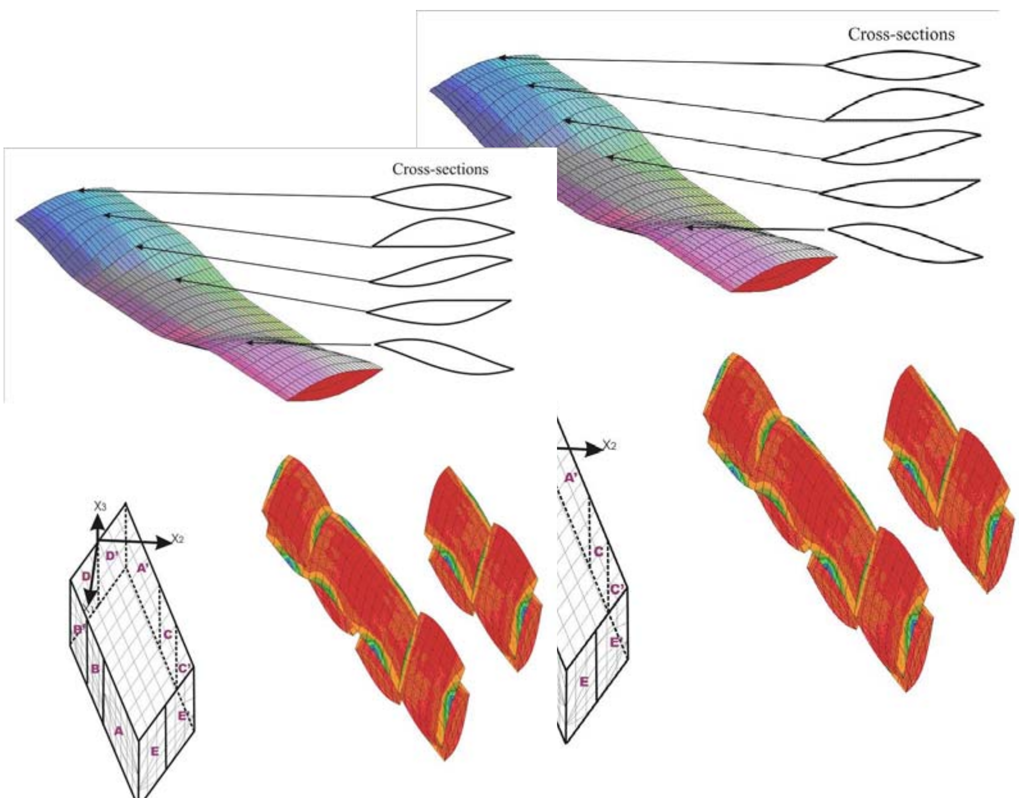

Figure 3. Representative Volume Element (RVE)